TEST OF THE MERCURY ARC
& THE MURPHY ELECTRICITY RECTIFIERS

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A COMPARATIVE TEST OF THE MERCURY ARC
AND THE
MURPHY ELECTRICITY RECTIFIERS.

A THESIS

PRESENTED BY

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ALFRED C. LOHSE AND
WILLIAM P. McGUIRE

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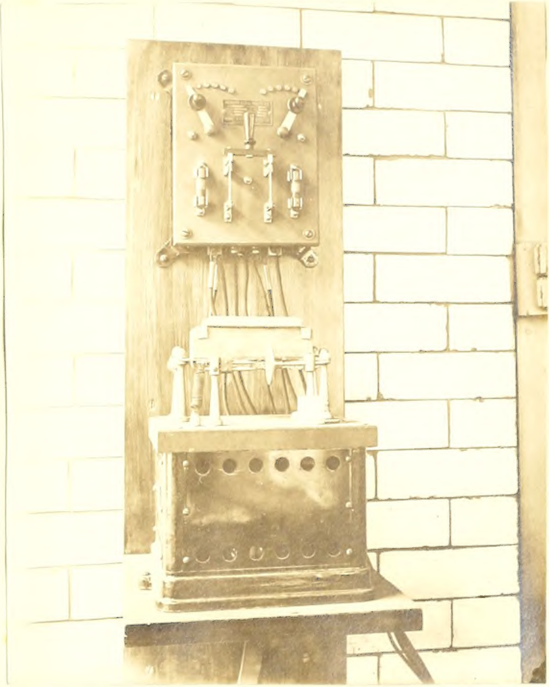

The Murphy Electricity Rectifier.

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The Mercury Arc Rectifier.

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TABLE OF CONTENTS.

Page.

Introduction 1.

Method. Test of the Mercury Arc Rectifier. 3.

Theory. The Mercury Arc Rectifier. 14.

Method. Test of the Murphy Rectifier. 19.

Theoretical Explanation of the Operation of the Murphy Rectifier. 21.

Directions for Operating the Murphy Rectifier. 26.

Explanation of Tables, Curves and Diagrams. 28.

Conclusion. 33.

Instruments. 36.

Bibliography. 37.

INTRODUCTION.

New applications and uses of electricity in various industries, have greatly increased the need of efficient forms of rectifying devices. This need has developed on account of the growing tendency of large generating stations of confining themselves to the production of alternating current only, for power and lighting. Such a tendency has resulted from a greater ease of transmission in alternating current than in direct current circuits, due mainly to higher potential by use of transformers and saving of copper over direct current circuits.

Therefore any problems of rectification are left mainly with the consumer, who necessarily requires a high efficiency type of rectifying device for direct current application. Among the many and common uses, where unidirectional currents have been made possible

of rectifying device for direct current application. Among the many and common uses, where unidirectional currents have been made possible from alternating current sources of supply due to rectifiers, may be mentioned the charging of telephone storage batteries, automobile batteries for power and for ignition coils, electro-magnets, small direct current motors, moving picture machines arcs and direct current series arc lighting.

The work of this thesis will involve a study and tests of two forms of commercial rectifiers, namely a mercury arc rectifier, made by the General Electric Company and a new type of solid rectifier made by the Murphy Electricity Rectifier Company of Rochester, N.Y.

The Mercury Arc Machine has a full load capacity of twenty (20) amperes at one hundred and ten (110) volts direct current. The alternating current voltage is two hundred and twenty (220) volts.

METHOD.

TEST OF THE MERCURY ARC RECTIFIER.

The first step to be decided upon in the testing of these rectifiers, was to calibrate the necessary instruments used in the testing. These instruments were calibrated by direct comparison with standard instruments and on account of the limited supply of instruments, it was found necessary after their calibration to change the same on the direct current side. This was on account of the wave shape of the current and the E.M.F. on the direct current side of the rectifier, the voltmeter readings and the ammeter readings gave low indications. This fact was due to the induced currents set up in the movable frame in the coils of the instruments. To enable more precise results alternating current instruments were used on the direct current side. The voltmeter was of the dynamometer type and the ammeter of the magnetic vane type.

Since the instruments are affected by stray fields, it was found by reversing the terminals that they gave different readings for the same impressed voltage and load. This error was corrected by supplying reversing switches in both the volt- and ammeter circuits. The wattmeter, also being of the dynamometer type, ~~it~~ was also affected by the stray fields, and since the current coil is in series with the ammeter and the potential coil parallel with the voltmeter, upon reversal the current and pressure coils in the wattmeter were also reversed. These instruments were calibrated Feb.1st, 1911, and their correct readings taken from the calibration curves.

The rectifiers were tested with potentials of different wave shape. The first one was an approximate sine wave, while the second one had the peaked wave form. The generator supplying

the near sine wave was built by the General Electric Company, single phase, 220 volts and was driven by a fifteen Horse Power Interpole, 110 volt direct current motor. The motor drove the generator at a speed giving sixty cycles per second. This frequency was maintained constant by a rheostat in the field of the motor. The impressed voltage of the generator was kept constant by a rheostat in the generator field. The generator was separately excited from the same source which supplied the motor.

The voltage of the generator was indicated by a 250 voltmeter of the dynamometer type, and the frequency by a frequency meter. These two instruments were connected across the terminals of the generator. The wattmeter used had a three K.W. rating, the current coil fifty amperes and the pressure coil 150 volts. Since the voltage used was 220, which was above that for which the pressure coil was designed, a resistance was placed in series with the coil. The resistance of the pressure coil as measured gave a value of 5772.4 Ohms,

the total resistance required in this potential circuit is 220 divided by 150 multiplied by 5772.4 or 8466.2 Ohms. This gives the maximum allowable pressure upon the potential coil, consequently the external resistance required in series with the potential coil is 8466.2 minus 5772.4 or 2693.8 Ohms. This results in a constant by which the wattmeter readings must be multiplied to give the true power. The value of this constant is 8466.2 divided by 5772.4 which equals 1.466. This resistance was not included in the circuit when the wattmeter was calibrated, the first time, but was included upon a re-calibration at the end of the test. The ammeter in the supply circuit had a capacity of thirty (30) amperes and was of the alternating current type.

The wattmeter in the direct current side had a capacity of three (3) K.W., its full load current rating being (25) twenty-five amperes, While the pressure coil was designed for 150 volts. The current through the current coil was reversed by a switch marked C in the diagram, figure (3).

When the double pole, double throw switch was thrown into position (1) and the small switch (A) connecting the terminals (C) and (D) was closed, and the switch marked (B) connecting the terminals (E) and (F) was open, the current in the current coil passes through as indicated by the solid arrow. Upon placing the double pole double throw switch in the position (2), as shown by the dotted lines and the small switch (B) closed, the current passes through the wattmeter coil as indicated by the dotted arrow, which is in the reverse direction. The E.M.F. of the potential coil is reversed by a small double pole, double throw switch, marked (P) in the diagram. For the position of the current switch as designated by the solid lines, the solid lines of the potential switch indicate the proper position for the correct reading of the wattmeter. The position of the current switch, as shown by the dotted lines, requires that the potential

switch be thrown in position (2), as shown by the dotted connections on the potential switch. Since the voltmeter is connected across the pressure coil it was also reversed when the wattmeter readings were taken in the opposite direction. A lamp-rack on the direct current side served as a load.

The instruments were read at one quarter, half, three quarter, full and 25% over-load. The potential on the direct current side was maintained as near as possible at 115 volts at the different loads. As the voltmeter read but 120 volts and being the only one of the dynamometer type at hand, it can be said that this data was taken at constant potential, but of course as the load increased, the pressure could not be kept at the maximum value. A resistance load was also used and since the voltmeter read up to 120 volts only, a direct current voltmeter was used, which read up to 150 volts; but a as explained in the first part of the testing, this

voltmeter had to be calibrated with a dynamometer type as the standard on this wave shape of E.M.F. Conscequently this part of the testing did not require any reactance in the direct current circuit except the permanent reactance used for the operation of the rectifier. It was thought that the loss of power in this reactance at constant potential would give a different efficiency at different loads but that this loss should not be charged to the rectifier, since it was operated at a certain desired potential.

The resistance of the reactance from point to point was taken by the drop of potential method. From this resistance, knowing the notch at which the reactance was and the load current, we can calculate the loss of power due to the reactance, which would simply be the square of the current times the resistance.

The efficiency, which compared the output on the D.C. side to the input on the A.C. side we termed the "Commercial Efficiency".

In the second testing a generator giving a peaked wave was used. The voltage of the generator was 1100 volts, single phase and direct connected to a 35 H.P. direct current motor. The speed of the motor was controlled by its field rheostat and the generator voltage by its field rheostat, the field being separately excited. The power from the generator was transmitted to two Westinghouse transformers of [illegible] K.W. capacity each, the transforming ratio of which was one to ten. The high tension sidesof these transformers were connected in parallel, while the secondaries were connected in series, so as to give 220 volts.

The frequency meter and the voltmeter were connected directly across the line andthe wattmeter connections were the same as in the

first test and these are shown completely on the diagram, (fig.). The efficiency of the rectifier for this wave shape was also calculated as for the approximate sine wave. At the end of this test, the bulb broke down and as the intention was to obtain oscillograms of both the current and the E.M.F. waves on both sides of the rectifier a new bulb had to be substituted. The old bulb was manufactured May 6th, 1906. The scheme of connections is shown in figure (3). The power was supplied by the 1100 volt generator and the wave shape investigated(by the)at the different loads indicated by the wave diagrams. The waves were traced and enlarged five times their original size by means of a pantagraph. It was first tried to photograph the waves, but this proved unsuccessful for the many different trials made.

The E.M.F. waves on both the A.C. and the D.C. side were first investigated. Two wires were directly connected across the line terminating at the potential plugs on the oscillograph. The oscillograph circuit included the proper resistance so that the height of the wave could be adjusted at will.

The current waves were next to be investigated. Since the current on the A.C. side was of too large a value as to be sent directly thru' the oscillograph shunts, a current transformer with a one to five (1:5) ratio was used. The high current side was connected in series with the rectifier, while the low current side was directly connected to the galvanometer and, in order to regulate the height of the wave, a variable shunt was directly connected across the galvanometer. Since there were no intermediate shunts suitable

for investigating the D.C. wave, the current on the D.C. side was sent through a carbon plate rheostat and the galvanometer connected to two movable brass plates which could be placed anywhere in the carbon plate rheostat, so as to give the desired height to the wave. [The connections are all shown on the diagram fig.( )]

THEORY.

THE MERCURY ARC RECTIFIER.

The Mercury Arc Rectifier is not a new type of rectifying device, but it is one whose field of application has rapidly broadened. Its principle of operation may be briefly mentioned.

Some gases, under proper conditions, will allow the passage of an electric current through them but in one direction only. A gas of such a nature is Mercury Vapor. The significance of the above statement is at once apparent. If a very high voltage ([illegible],000 volts) is impressed upon two electrodes in a glass bulb containing mercury in Vacuuo and an arc can at once be started, the mercury vapor formed therefrom will become ionized and allow the current to flow between the electrodes but in one direction only. Once started, the voltage across the electrodes will drop to a low value (4 or 5 volts). The direction of flow of the current is from the positive electrode or anode into the Mercury Vapor and then to the negative electrode or cathode.

If the terminals should be changed or for any reason the voltage should become reversed so that the negative electrode become positive, the current would cease to flow, since, in order to do so, a new negative would need to be formed, which is extremely difficult under such circumstances.

Figure I. shows a diagram of the general connections of the General Electric Company's type of rectifier to be tested. The glass tube is made long to enlarge the volume of the cooling chamber. The bulb contains two graphite anodes, AA', and one mercury cathode B. The graphite anodes are made of star section placed in separate chambers. The current is led in by platinum wires melted into glass over a considerable length. The platinum wires are of small section, there being two one millimeter diameter wires to each electrode. The leading in wires for the mercury cathode end in

small metal plates which almost fill up the contracted bulb-end and so protect the junctions against any of the mercury during movement.

The two anodes are connected to opposite sides of the A.C. supply and through reactances to the same side of the load. During the first half of a cycle the current flows from one anode and during the following half cycle from the other anode to the cathode and through the load and reactance to the other side of the supply. Thus only the upper halves of the supply waves (0°-180°) are sent through the ionizing vapor. A pulsating D.C. is produced varying from zero to the maximum.

To start the action of ionization a small starting anode (C) is used. By rocking the tube slightly, a mercury bridge is made between (C) and the cathode, and an arc is drawn as the tube returns to the vertical position. The ionized

vapor being thus formed, the working anodes AA' become active.

Since the D.C. is pulsating it is necessary that some device be provided for maintaining the working arc during periods when the A.C. supply curve is passing through zero value for otherwise the cathode would cease its excitation. This is the function of the reactance, which is connected directly across the supply mains. One reactor (E) charges as the current wave rises from zero to the maximum through anode (A) and discharges inductively, the current continuing in the same direction as the main flow. The next wave causes the current to pass through the reactor (F) and anode A' and as before the reactance prolongs the current flow until the second wave overlaps the first wave before the current can reach a zero value. Therefore the current never reaches a minimum of zero and the cathode excitation is always maintained. The undulations of the waves are necessarily made shallow-

er and therefore the pulsations of the load current become less pronounced.

Figure 2. shows a more detailed diagram of the rectifier. The relative positions and connections of the glass tube, starting resistance and reactance are given. The reactors are mounted in a cast iron box case which stands on the floor under the panel. The equipment provided with the set further includes an ammeter, voltmeter, circuit breakers, fuses, a double pole A.C. line switch, rheostat and a double throw single pole starting switch.

METHOD.

THE TEST OF THE MURPHY RECTIFIER.

The Murphy Rectifier was tested in the same manner as the Mercury Arc Rectifier. The connections of the instruments used in the test and the generator supplying the power are shown in the figure (3). The test was carried out at 1/4, 1/2, 3/4, full load and 25% overload. Great difficulty was experienced in reading the ammeters and wattmeters, since the current and voltage were not constant for every load. This is due to the variable resistance of the air gap between the graphite blocks marked (G) in the diagram of connections, figure (4). The first test was made with the generator giving the approximate sine wave, whose voltage was kept constant by its field rheostat and the frequency by varying the field of the motor. In testing this rectifier it was not necessary to use external resistance in the potential circuit of the wattmeter , since the voltage required by

the rectifier was only 120 volts. As great difficulty was experienced in obtaining the correct reading, the reversed readings on the D.C. side were taken and the average of these two readings taken as the true reading.

The second test was made with the generator giving a peaked wave. This generator was that used in the test of the Mercury Arc Rectifier. The power was delivered to the same single phase transformer used previously, which reduced the voltage to 120 volts. The voltage of the generator was kept at a value giving 120 volts at the secondary of the transformer. The frequency was maintained at 60 cycles. The wireing diagram for this test is exactly the same as in fig.(3) excepting that the voltage is stepped down through the transformer.

THE THEORETICAL EXPLANATION
OF THE
OPERATION OF THE MURPHY RECTIFIER.

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Since it is necessary in a rectifying device to regulate the A.C. power in such a manner as to be directly transformed into direct current power, or at least into a pulsating direct current, the machine must have some device which will utilize a part or parts of the A.C. wave to produce this desired result. In the Mercury Arc Rectifier both sides of the A.C. wave were used, while in this rectifier only one loop of the complete wave is transformed. The principle involved in the operation of this rectifier is that of a current passing in one direction only between two unlike metals. These metals consist of a nickel disk and a wire loop made of an alloy of platinum and iridium.

Since all commercial voltages, which are used inside of a residence or other private place at present are only 110 or 220 volts, which pressure is not sufficient to break down an air-gap, a special transformer is used in this machine to step up the voltage sufficiently so as to cause

break-down of about 1/2 inch air-gap. The transformer used for this purpose is marked (S) on the diagram of connections, fig.(4). Across the terminals of this transformer is placed a condenser (J). The object of this part of the apparatus is to break-down the air-gap between the graphite blocks (G). A small transformer, (H), is connected to the loop, keeping the same at a certain temperature, as this temperature is found to assist the voltage in the rupture of the air-gap. The primary winding, (P-1), is the main winding for the transformers (H) and (S). The winding (P-2) is the auxxiliary direct current primary winding. The inductances marked (L) prevent any high frequency oscillations from passing through the direct current load. The regulating resistances (R-1) and (R-2) are mounted on the small switchboard which controlls the E.M.F. impressed upon the direct current load and the E.M.F. produced in the transformer (S)

to break down the air-gap. Upon investigating the E.M.F. at the direct current terminals of the rectifier by means of the oscillograph it was found that the maximum E.M.F. was 100 volts, while the effective value as indicated by the voltmeter was but 29 volts. This peaked wave produces an insulation strain on all the apparatus in the direct current side.If the rectifier is adjusted so as to give the maximum effective voltage, which is about 48 volts, the insulation will be subjected to a strain of approximately 160 volts. This was the maximum pressure which could be obtained with the machine loaded, but with no load the voltage was found to rise to about 90 voltsConsequently this Voltage produced a strain of about 300 volts on the insulation.

The diagram showing the impressed E.M.F. on the rectifier and the resulting direct current

E.M.F. shows that the first half of the alternating current wave only is being utilized, while for the remainder of the cycle the direct current E.M.F. is of zero value. This fact alone tends to maintain a low efficiency of the machine. That the rectifier has a large inductance is shown by the low power factor. It was found that on overload the value of the resistance in the gap formed by the graphite blocks was so reduced as to short circuit the gap. The amount of power flowing through the line being sufficient to deflect the needle of a 50 ampere meter clearly off the scale. This short is not disasterous to the machine but may damage the instruments.

The distance between the graphite blocks is adjusted by means of a gauge accompaning the rectifier. The distance apart of the carbons is about one millimeter. The distance between the

loop and the nickel disk is so adjusted as to permit but a single or at the most three to four sparks to pass. When more that this number of sparks pass between the loop and the disk, the color of the spark, which before had the characteristic blue of a condenser discharge, is now red or a hot spark and where previously we had a snappy discharge a discharge similar to the brush effect occurs. The E.M.F. now produced on the direct current side is distinctly alternating at times, that is, every half second or so the supposed direct current wave would fill in both sides of the zero line as indicated by the oscillograph.

DIRECTIONS FOR INSTALLING AND OPERATING THE MURPHY ELECTRICITY RECTIFIER,

(As Furnished with the Machine).

The rating of the rectifier is 10 amperes at 120 volts, which is for the A.C. side. The rectifier should be mounted in an upright position on brackets or some suitable support.

The switchboard should be mounted in a vertical position (terminal end down) in close proximity to the Rectifier. Connecting wiring must correspond with accompanying diagram and ends of wire should preferably terminate in lugs. The plus end of the battery should be connected to the plus end of the Rectifier.

Adjustment of Graphite Electrodes.

The graphite electrodes should be adjusted so that the accompanying gauge will touch both electrodes yet pass freely between them.

Adjustment of High Tension Valve.

First-Move levers at top of the switch board to the inner contact points "A".

Second-Close the switch.

Third-Adjust both levers *Equally outward* from "A" until *not more than two or three* sparks pass simultaneously between the platinum-irido loop and the nickel disk. When more than two or three sparks pass the valve move the levers *equally inwardly* toward "A". Make this adjustment but once when installing the Rectifier.

To Operate-Simply close the switch.

In fig.(5):-A=Adjusting Resistance;
B=Batteries;
∼ =Line;
*=#14 B & S (gauge) Stranded Wire;
θ = #10 B & S)gauge) Stranded Wire.

TABLES, CURVE PLATES
AND
DIAGRAMS
OF THE
MERCURY ARC AND THE MURPHY RECTIFIERS.

TABLES.

The data and calculated results from the various tests are shown in the accompanying tables. Tables I. and II. concern tests made with a Mercury Arc Rectifier from the General Electric Company. These tables refer to alternators giving sine and peaked waved respectively. Table I. was obtained when using a G.E. 60 cycle 220 volt alternator. Table II. gives the data when using for a source of power a Westinghouse 1100 volt alternator. In both tables column (1) shows the point upon which the reactance arm was resting throughout the test; Column gives the various positions of the resistance rheostat to obtain a maximum D.C. voltage. The remaining columns are self-explanatory.

Tables III. and IV. show the results from exactly similar tests with the Murphy Rectifier. The same alternators were used. The applied voltage was 120 as shown in column (3). Column (1) shows the

positions outward of the twin reactance switches.

Both rectifiers show a steady increase of efficiency with load and a gradual decrease in the power factor for increase of load.

PLATES.

Plates I., II., III., IV. are current curves taken with a G.E.Co. oscillograph and enlarged to five times the original size with a K.&E. Pantagraph. Plate I. shows sine current waves of both A.C. and D.C. character taken from the G.E. Mercury Arc Rectifier. Plate II. shows peaked current waves of like nature from the same rectifier. Curves for 1/2 and full load areeshown on each plate. Plates III. and IV. show similar sine and peaked waves taken from the Murphy Rectifier when operated from the same alternators. The waves were taken at 1/2 and full load respectively.

Plate V. shows the complete efficiency curves and the Power Factor curves of the Mercury Arc Rectifier as obtained from the first run as given by Tables I. and II. for sine and peaked waves. Plate VI. represents a complete diagram of similar curves for the Murphy Rectifier, as plotted from data given by the first runs as shown byTTables III.and IV.

Plate VII. shows the actual working part of the complete set of Power Fac-tor Curves of the Murphy Rectifier using both the sine and the peaked waves. In Plate VIII. is shown the complete set of Efficiency Curves for the Murphy Rectifier for both the sine and the peaked waves. PlatesIX . and X. show similar working Efficiency and Power Factor curves of the Mercury Arc Rectifier using the sine and the peaked waves. Plates VII., VIII, IX. and X. are plotted to a large scale in order to show the

exact variation between the curves, due to the change in reactance points in each case. Each point on the curves is lettered fully to correspond with its proper place in the accompanying table. The interpretation of the notation on each of the curves will be understood fully by taking a sample illustration; thus:-T1RII indicates that the curve is taken from the data found in Table I. under run marked Reactance Point #2. This notation is the same for all the other curves found in this Thesis, the interpretation is exactly done the same way.

DIAGRAMS.

Figure 1 is a theoretical diagram of the essential parts of the Mercury Arc Rectifier. In Fig.(2) The internal connections and arrangement of the reactance and resistance rheostats of the Mercury Arc Rectifier are given. The complete wiring diagram of the same rectifier is shown in fig.(3) together with the arrangement of the various instruments.

Fig.(4) shows an internal diagram of the connections of the Murphy Rectifier and in fig.(5) the external wiring diagram of the same Rectifier and its resistance and reactance rheostat is shown. The interpretation of the various letters in diagrams (4) and (5) are as follows:-

G= Main gap between graphite electrodes.

V = Auxiliary, valve or spark gap.

P_1 = Main primary winding A.C.

P_2 = Auxiliary primary winding D.C.

H = Secondary winding for heating loop of V.

S = Main secondary.

J = Small Leyden jar type condenser to furnish disruptive discharge.

L = Protective inductances to prevent spark from injuring apparatus in circuit.

R = Resistance for regulating current in battery.

B = Battery under charge.

R_1 and R_2 = Regulating resistance in primary transformer circuit.

CONCLUSION.

The Murphy Rectifier.

The Murphy Rectifier tested was rated at 10 amperes, 120 volts A.C., but the machine was capable of over 100% overload, showing wonderful endurance for long periods. The Oscillograph current curves (Plates III. and IV.) indicate a highly pulsating D.C. current. From a comparison of these curves best results are indicated by use of the sine wave although a comparison of Tables III and IV. indicate, in some cases, a greater efficiency with the peaked wave. It must be remembered however, that the size of the spark-gap over the condenser as well as between the solid electrodes was the same for equal reactance points on each test. It was noticed that after a long steady run the solid electrodes became considerably blackened, which deposit furthermore increased the unsteadiness of the instruments.

The tables and efficiency curves show a steady increase of efficiency for increase in load, for both sine and peaked waves. The high reactance points also indicate a greater efficiency for the same condenser spark-gap. The power factor is very nearly constant, dropping but slightly for increased loads; it is higher for the higher reactance points. The average efficiency of the Rectifier is 68% and the average Power Factor .500.

The G.E.Mercury Arc Rectifier.

This rectifier had twice the capacity of the Murphy or Solid Rectifier. It was however incapable of as high an overload; 25% overload was the maximum at which the machine was tested. A sudden overload is liable to fuse the fine connecting wires at the electrodes inside the glass tube.

The Mercury Arc Rectifier showed a very steady current wave for both types of wave forms taken. The current was of a low nature in pulsa-

tions, i.e. the wave never reached zero value as dd did the current wave in the Murphy Rectifier. Test results were obtained from the sine wave. Tables I. and II. indicate an increase in Efficiency for increased load using the low reactance points, and and a slight but steadily falling off Efficiency for increased loads at the higher reactance points.

The average efficiency of the Mercury Arc Rectifier was approximately [illegible]%. The Power Factor was almost constant, showing but a slight decrease for higher loads. The mean value for the Power Factor was about .82 or 82.0%.

Instruments Employed During the Test.

A.C.Ammeter	#205834.
A.C.Voltmeter	#5246.
A.C.Wattmeter	#467.
D.C.Ammeter	#205833.
D.C.Voltmeter	#5091.
D.C.Wattmeter	#466.

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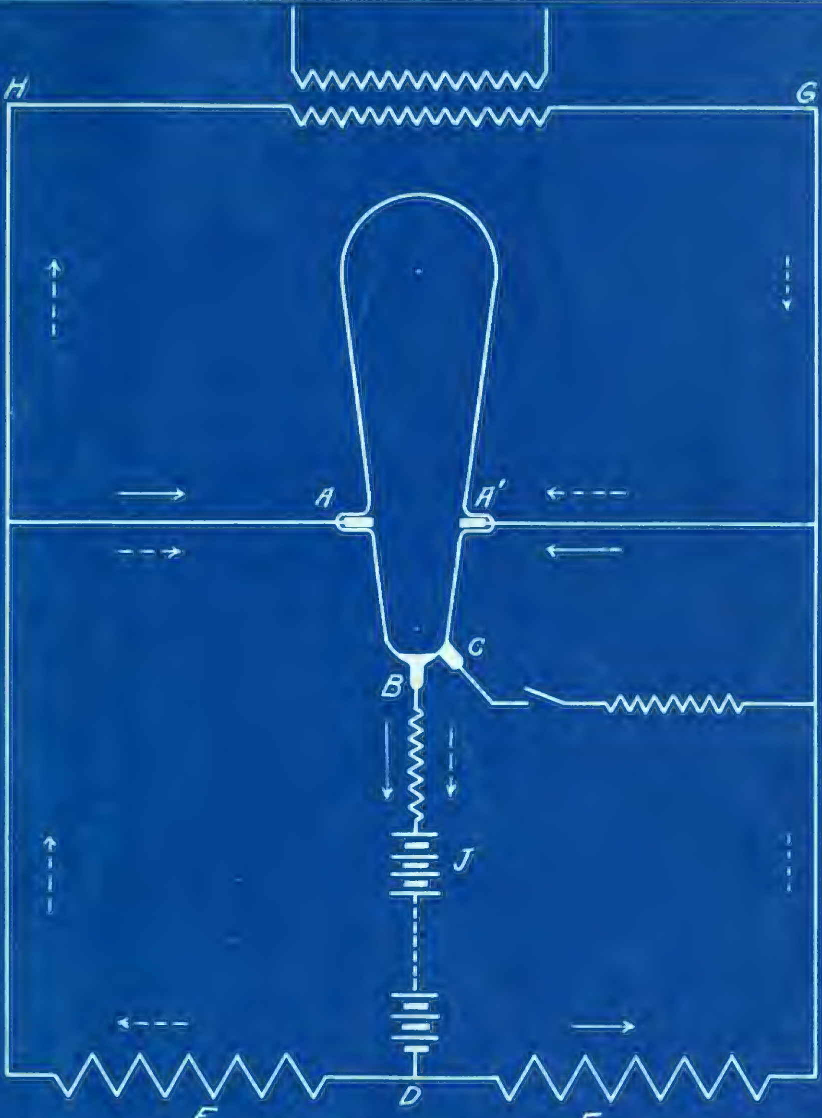
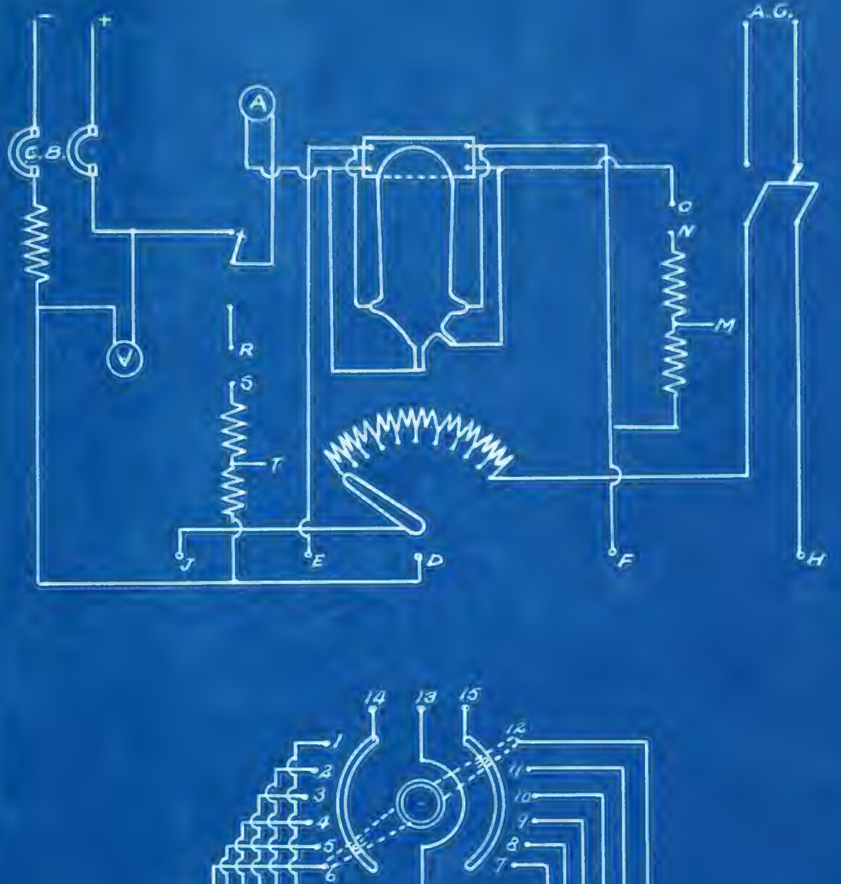
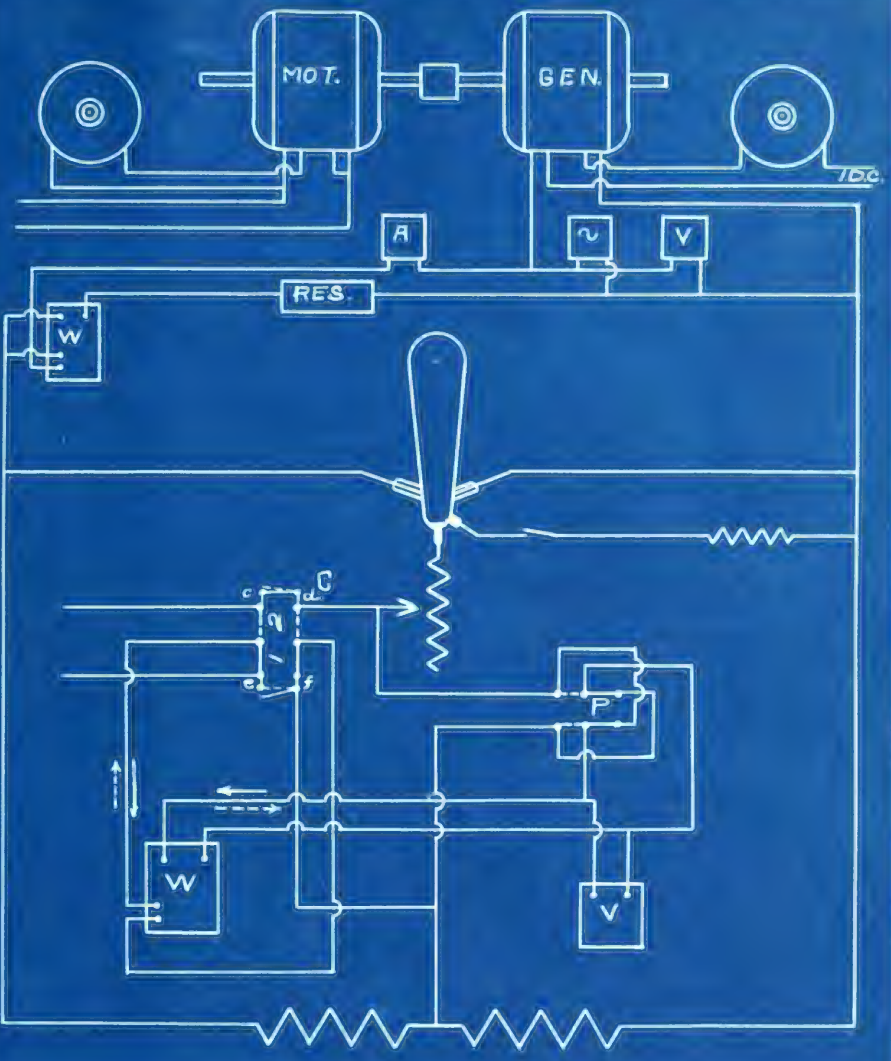


THEORETICAL DIAGRAM OF MERCURY ARC RECTIFIER

FIG. 1.



TERMINAL CONNECTIONS OF THE
Mercury Arc Rectifier. Fig. 2.



WIRING DIAGRAM OF
MERCURY ARC RECTIFIER
FIG 3.

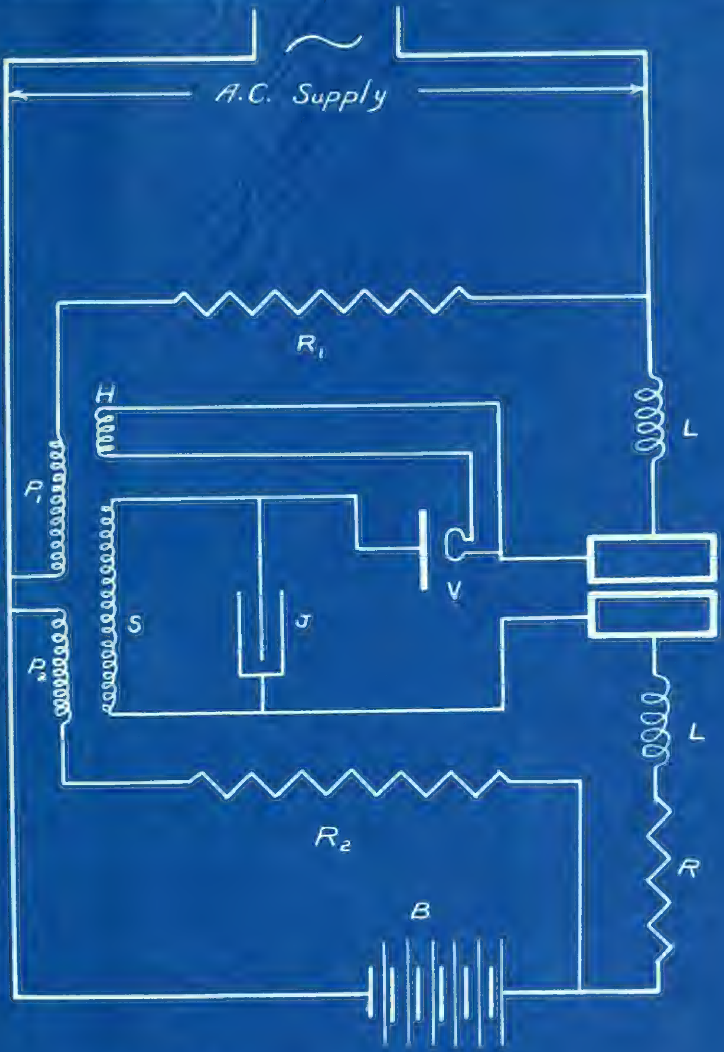
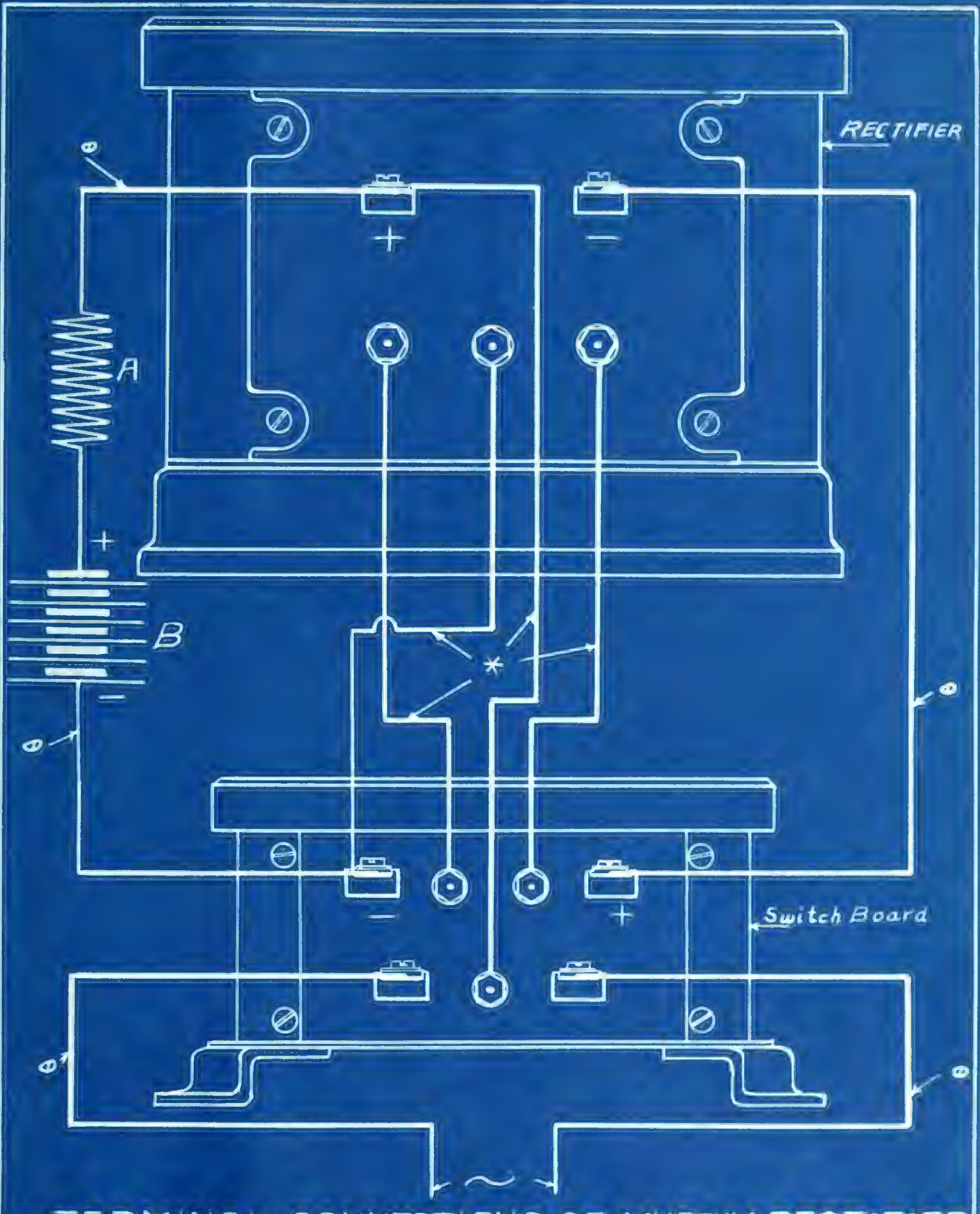


DIAGRAM OF CONNECTIONS.
of
MURPHY RECTIFIER.
Type A —
FIG. 4.



TERMINAL CONNECTIONS OF MURPHY RECTIFIER
FIG. 5.

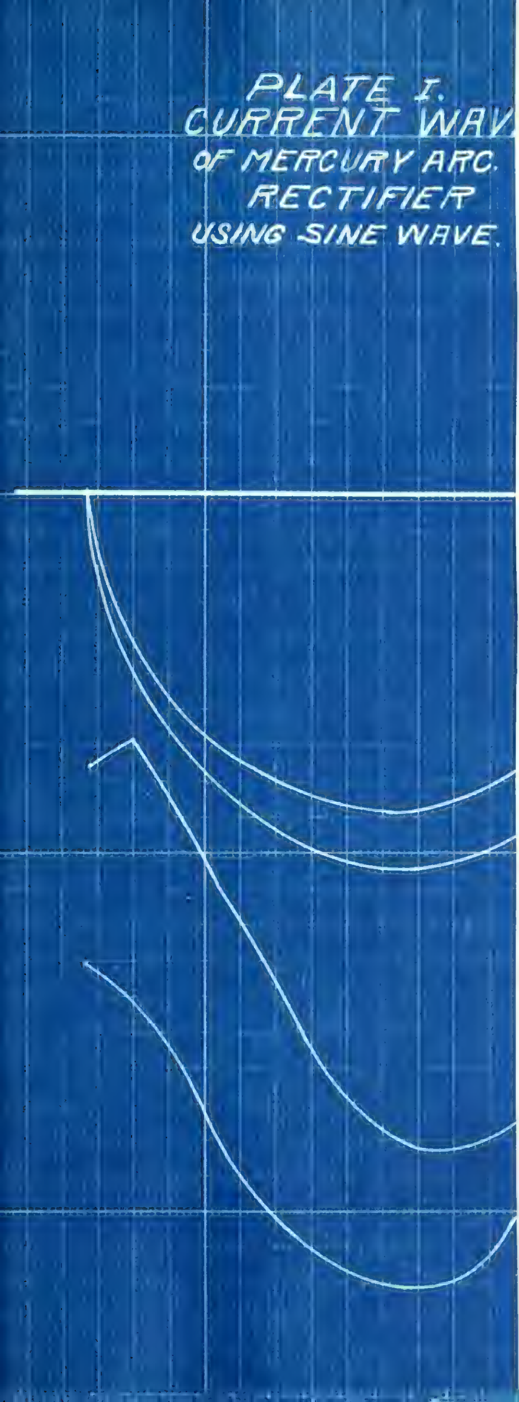


PLATE I.
CURRENT WAV
OF MERCURY ARC.
RECTIFIER
USING SINE WAVE.

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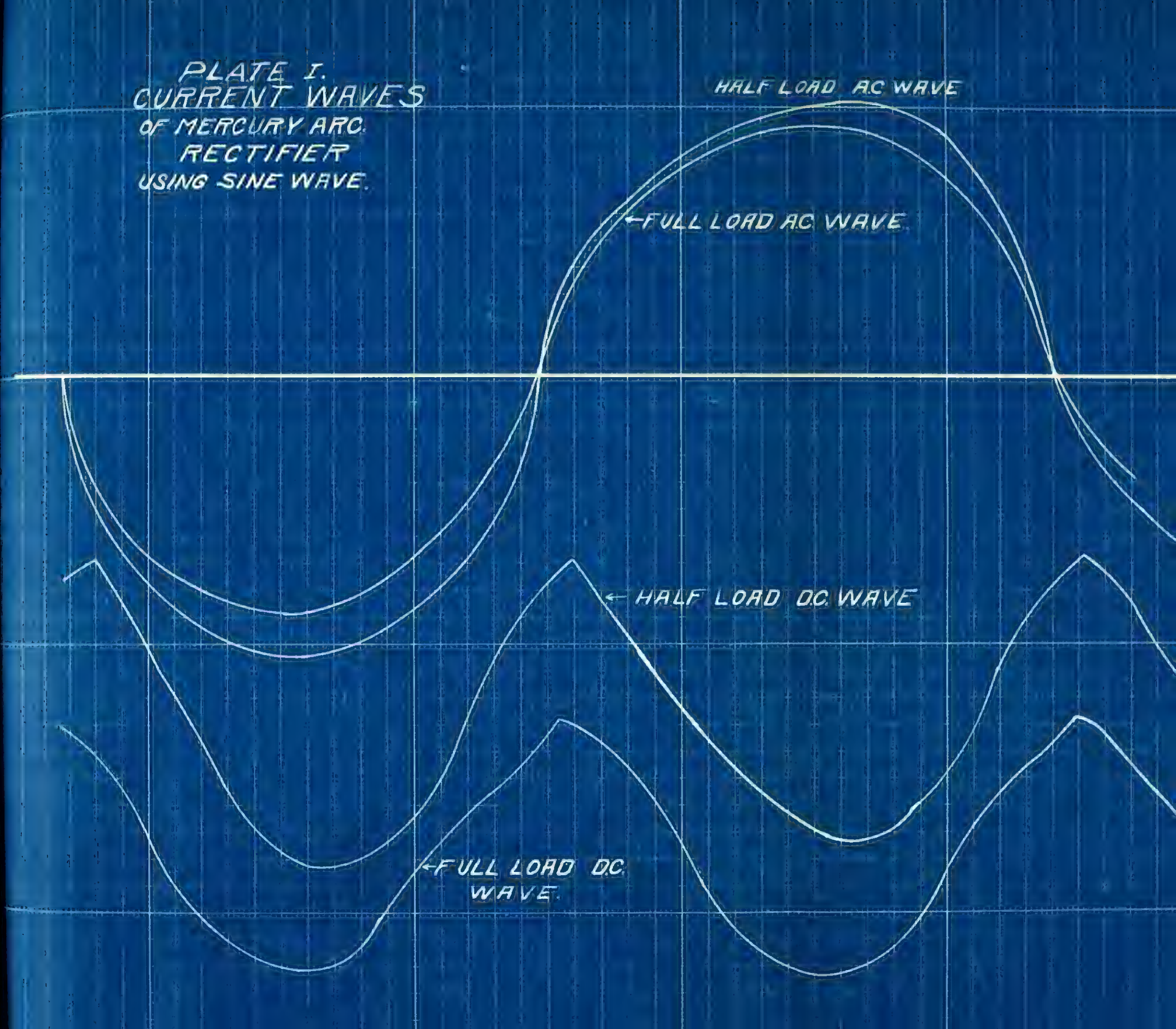

PLATE I.
CURRENT WAVES
OF MERCURY ARC
RECTIFIER
USING SINE WAVE.

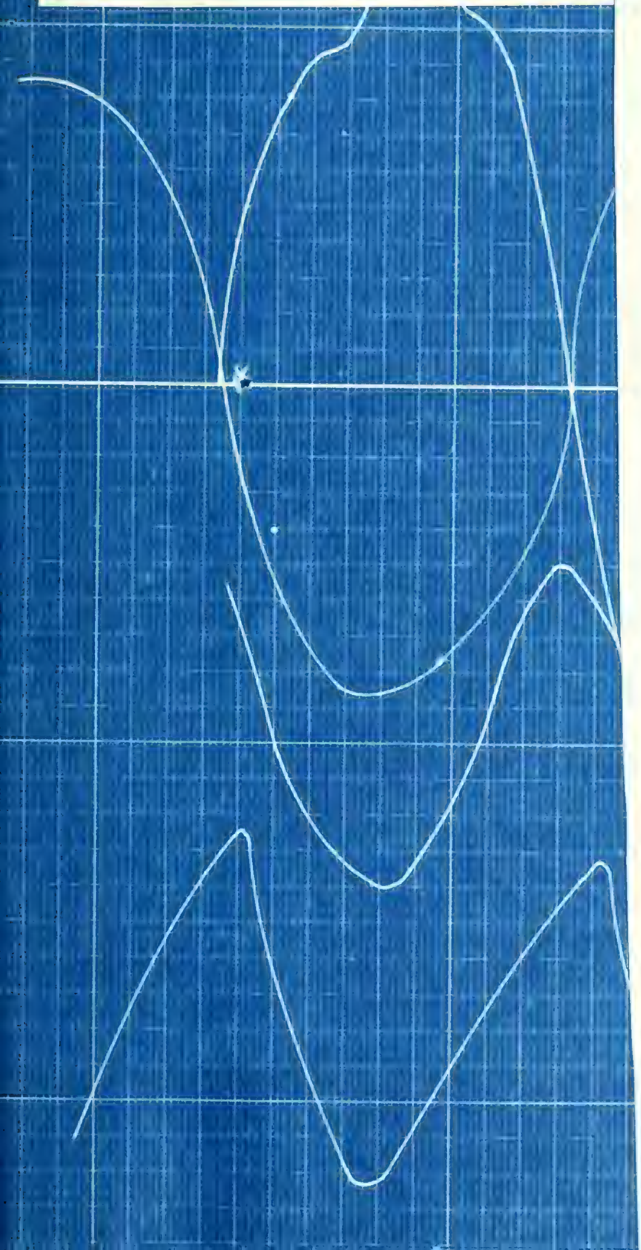

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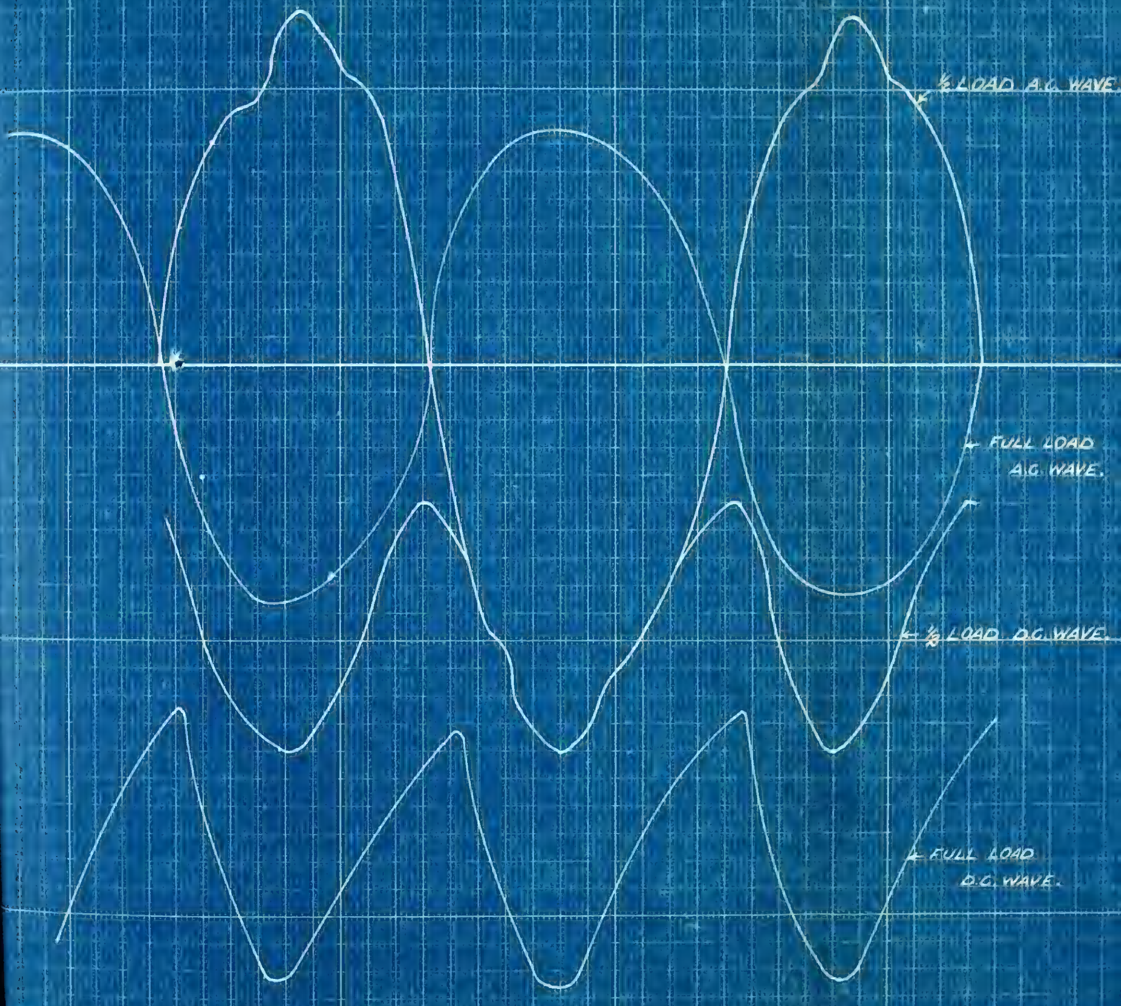
PLATE II.

LOAD CURVES OF
MERCURY ARC RECTIFIER
USING PEAKED WAVE.



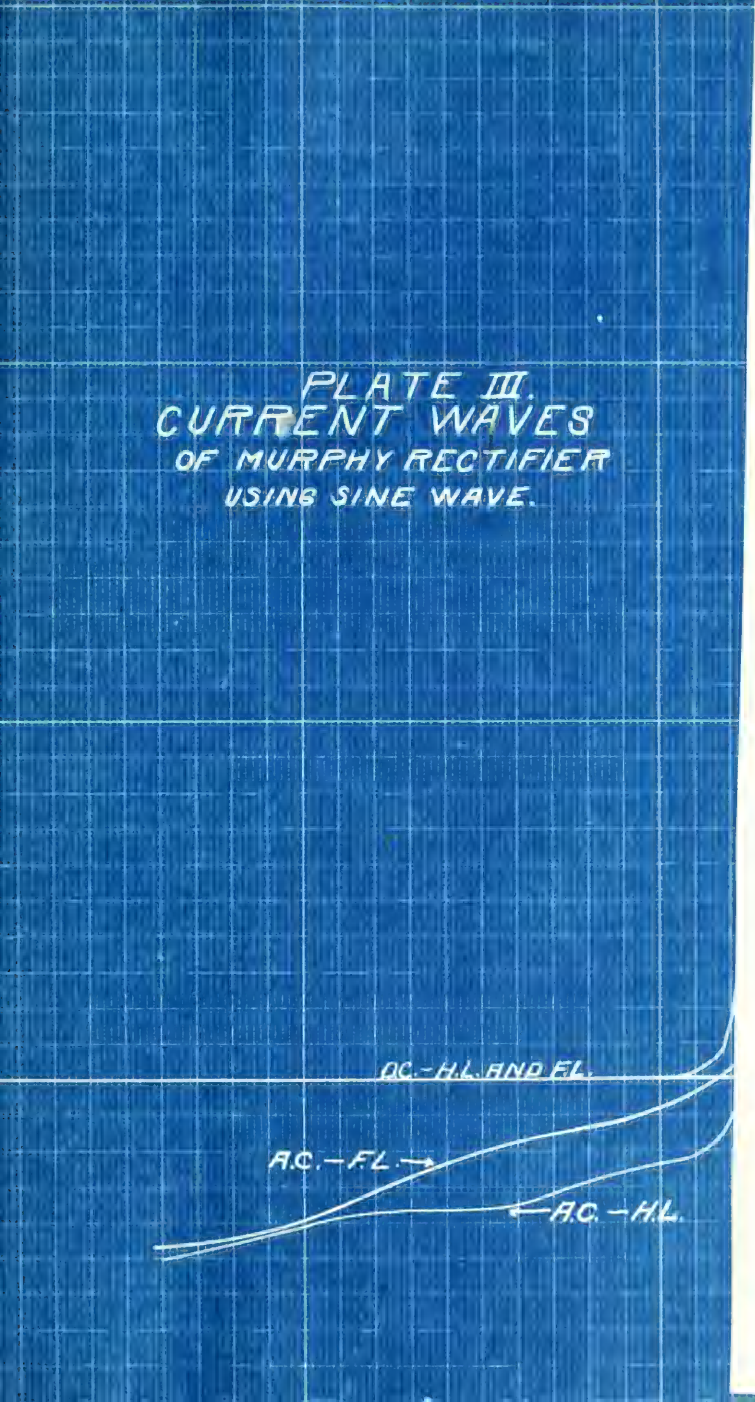


PLATE III.
CURRENT WAVES
OF MURPHY RECTIFIER
USING SINE WAVE.

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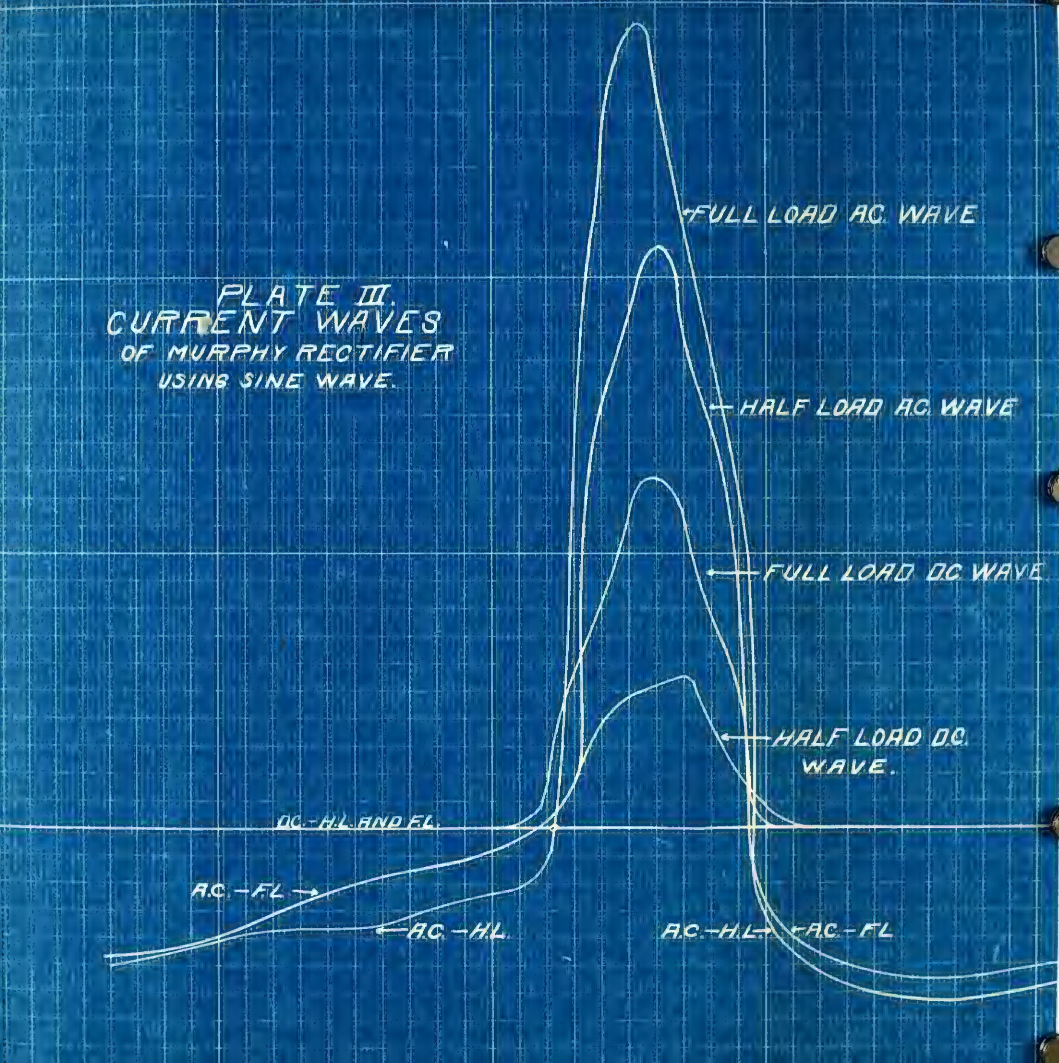
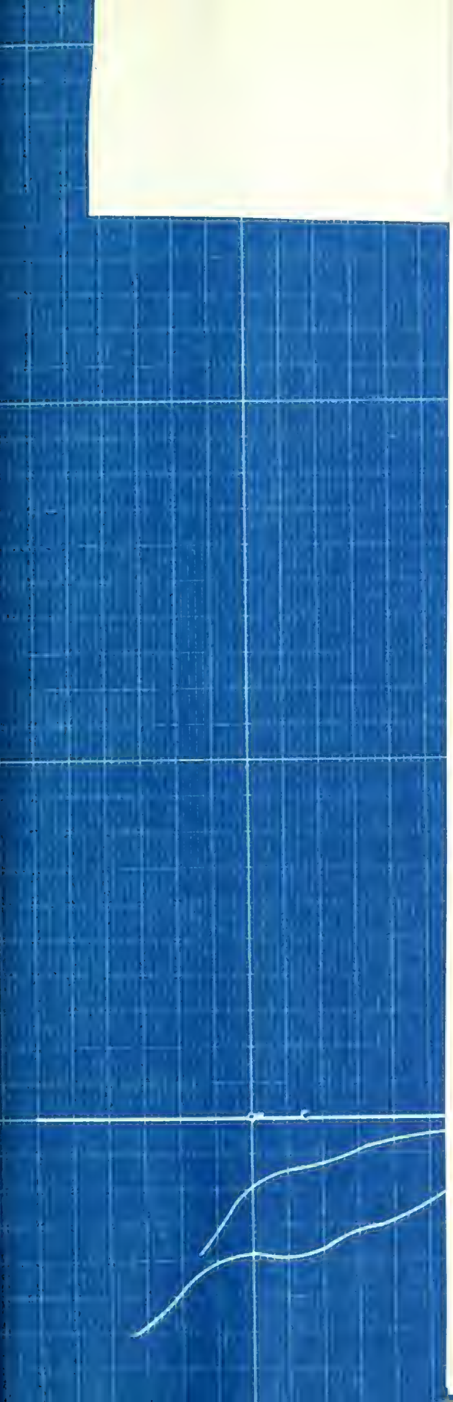
PLATE III.
CURRENT WAVES
OF MURPHY RECTIFIER
USING SINE WAVE.





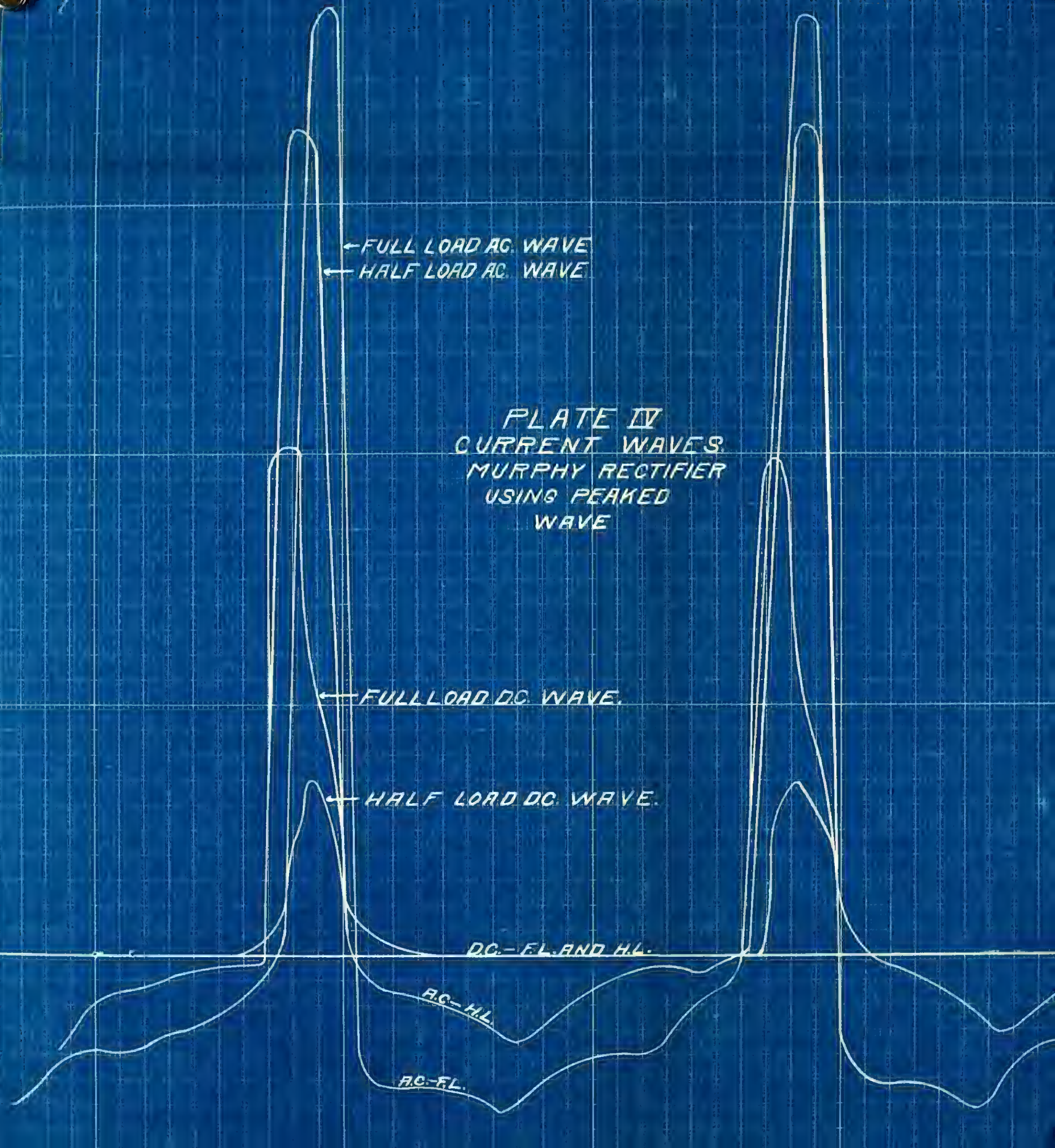


PLATE IV
CURRENT WAVES
MURPHY RECTIFIER
USING PEAKED
WAVE

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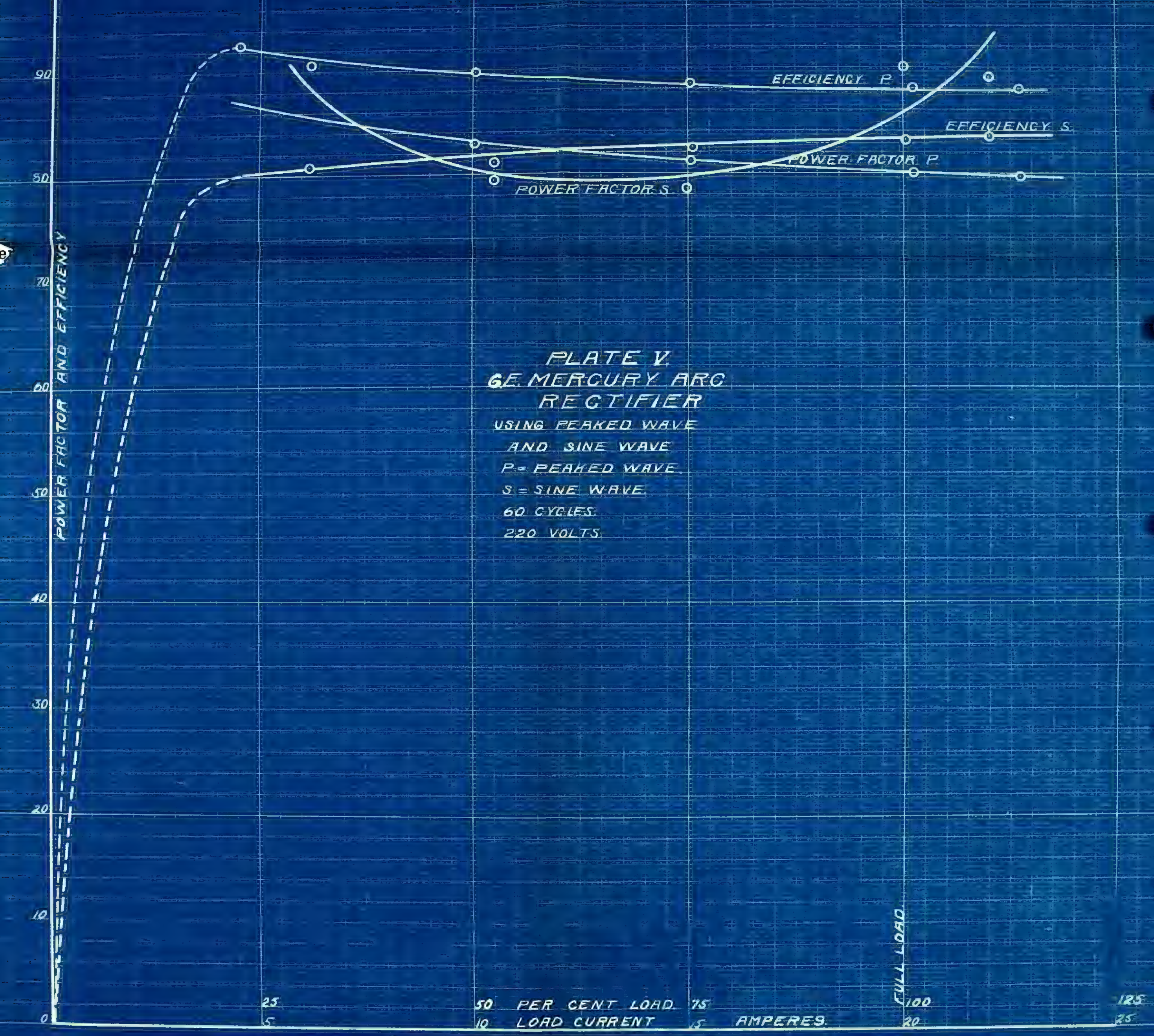


PLATE V.
G.E. MERCURY ARC
RECTIFIER
USING PEAKED WAVE
AND SINE WAVE
P = PEAKED WAVE.
S = SINE WAVE.
60 CYCLES.
220 VOLTS.

STANDARD PROFILE PLATE A 4×20
KEUFFEL & ESSER Co. NEW YORK

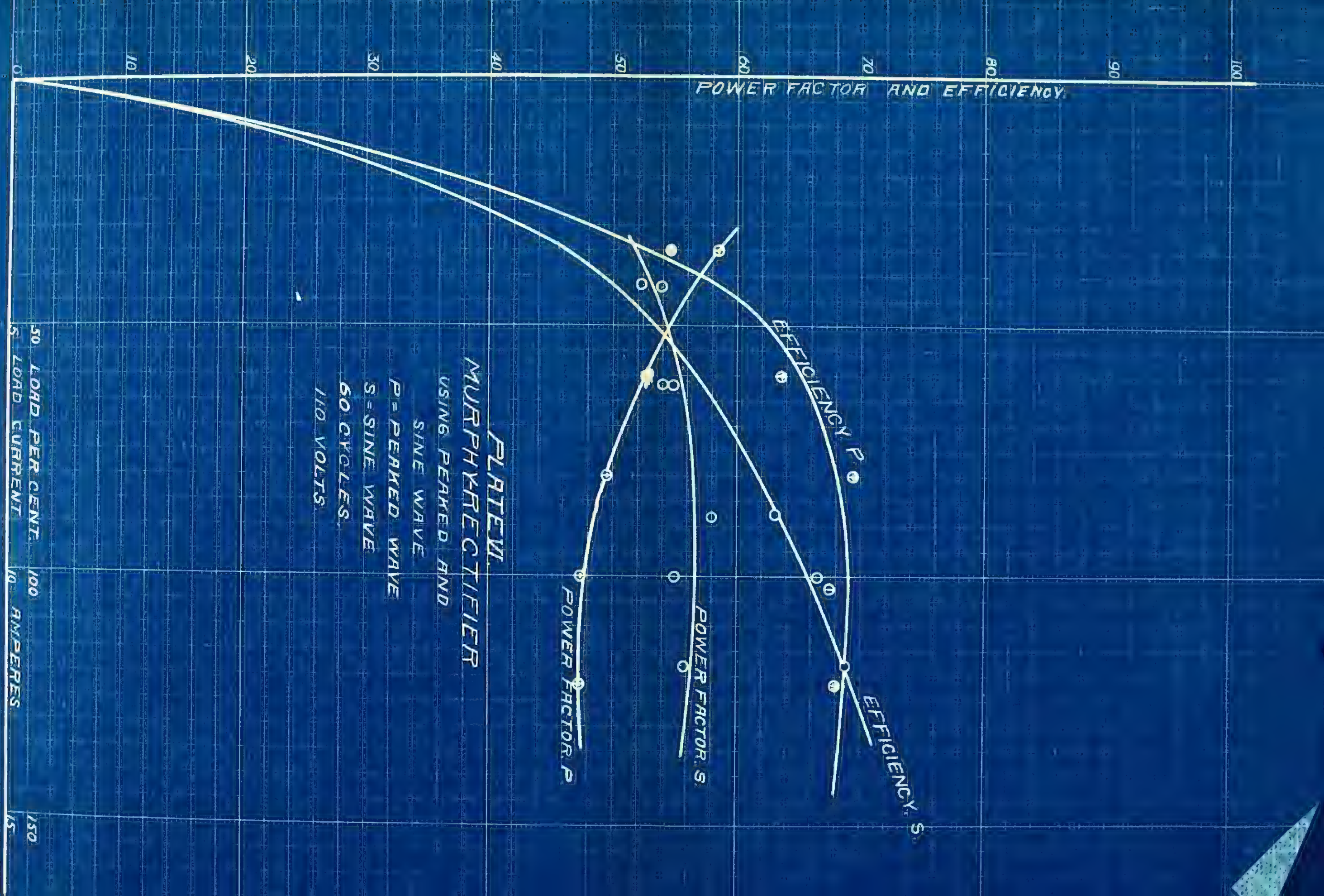


PLATE VI.
MURPHY RECTIFIER
USING PEAKED AND
SINE WAVE
P=PEAKED WAVE
S=SINE WAVE
60 CYCLES
110 VOLTS

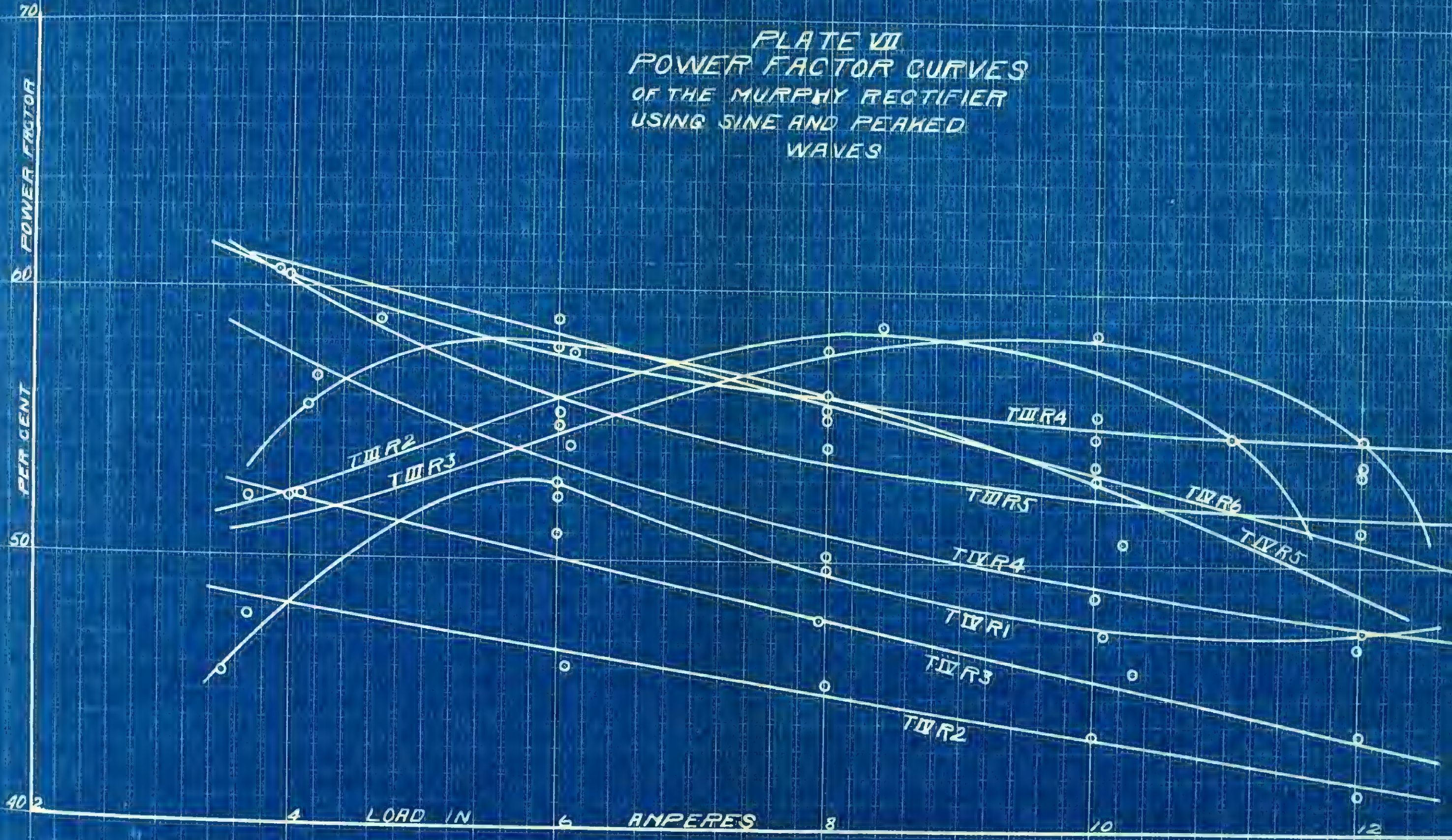
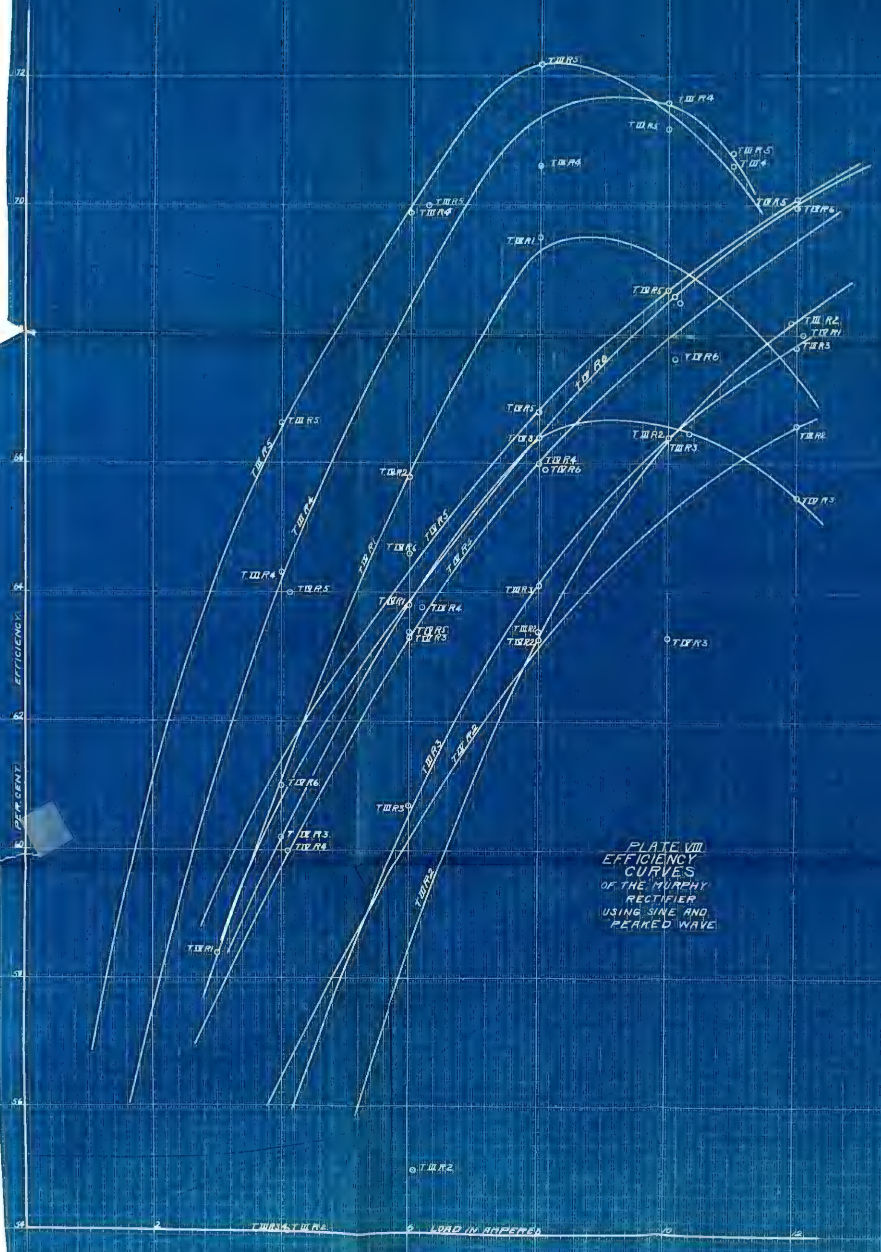


PLATE VII
POWER FACTOR CURVES
OF THE MURPHY RECTIFIER
USING SINE AND PEAKED
WAVES



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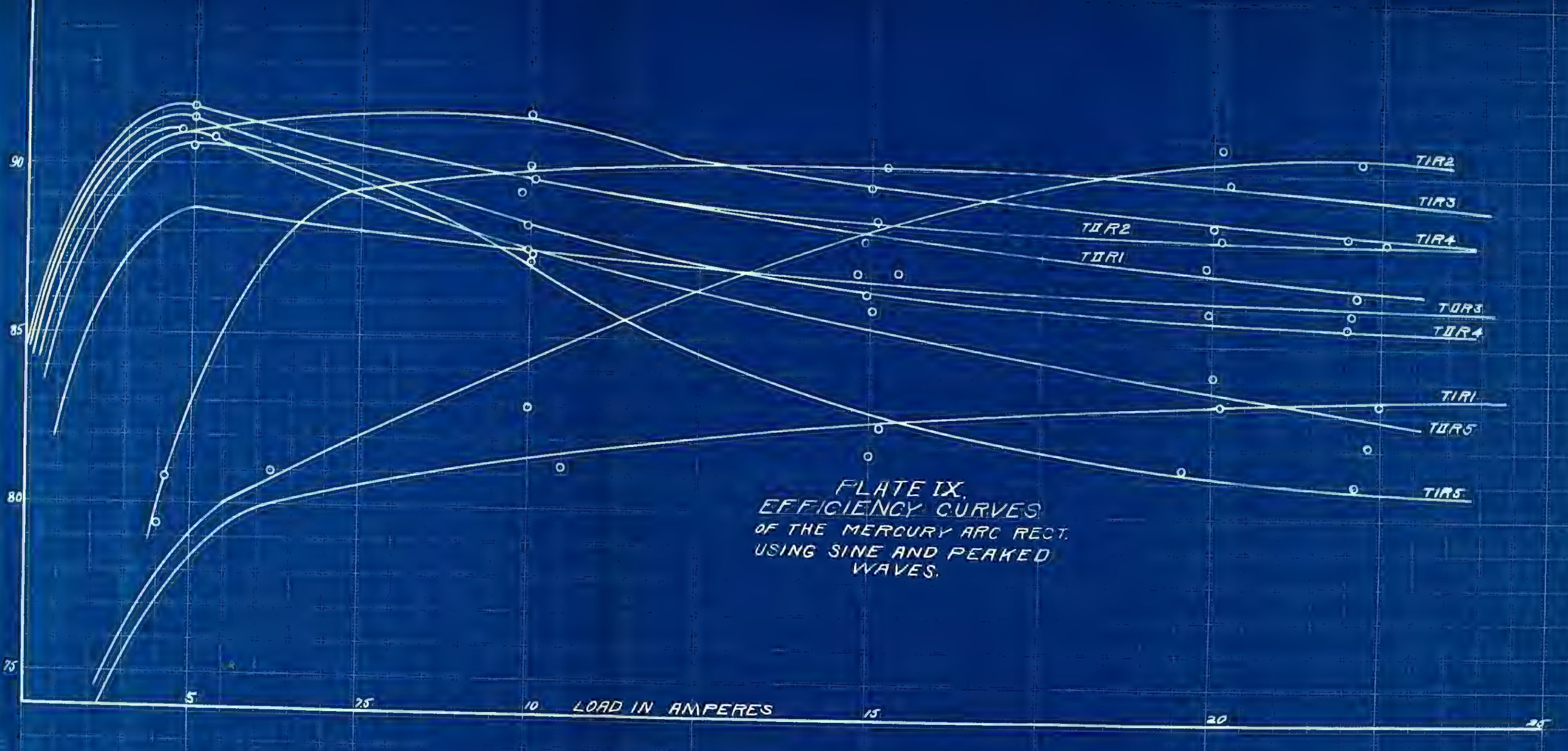

PLATE IX.
EFFICIENCY CURVES
OF THE MERCURY ARC RECT.
USING SINE AND PEAKED
WAVES.

5
5
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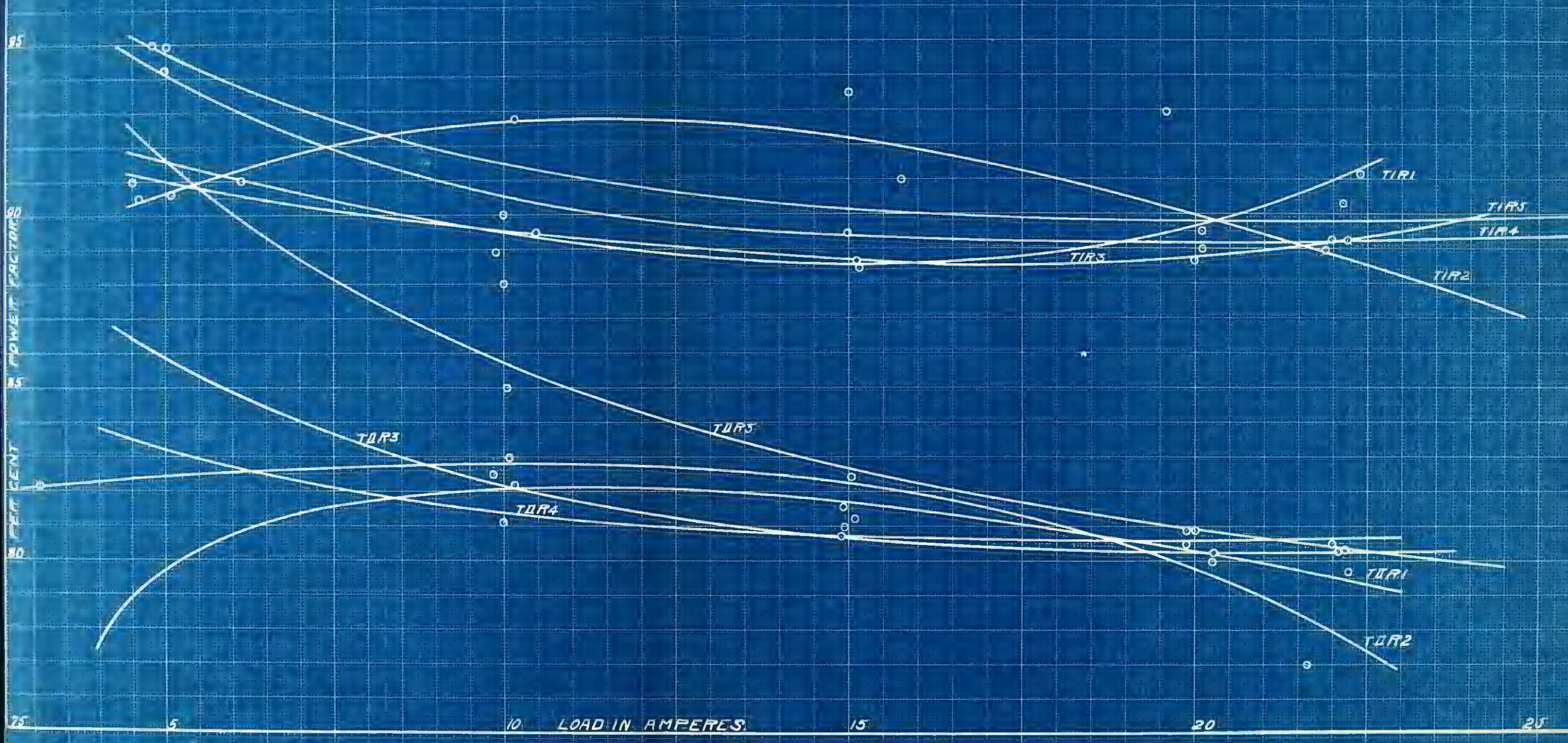
PLATE X.

POWER FACTOR CURVES
OF THE MERCURY ARC RECTIFIER
USING SINE AND PEAKED
WAVES.



TAB

DATA AND CALCULATIONS o

SINE WAVE. FREQUENCY

R	$I_{A.C}$	$E_{A.C.}$	KW_{AC}	EI_{AC}	P.F.	$I_{D.C}$
11	4.7	220	.94	1.84	.910	6.2
7	7.3	"	1.485	1.63	.895	10.5
4	11.1	"	2.46	2.46	.886	15.15
2	14.4	"	2.90	2.93	.926	19.8
2	16.0	"	3.23	3.52	.912	22.2

RUN 2 REACTA

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TABLE II.

DATA AND CALCULATIONS ON THE MERCURY ARC RECTIFIER

SINE WAVE. FREQUENCY 60 CYCLES. REACTANCE PT #1, RUN 1

R	$I_{A.C.}$	$E_{A.C.}$	$K.W._{A.C.}$	$EI_{A.C.}$	P.F.	$I_{D.C.}$	$E_{D.C.}$	$K.W._{D.C.}$	$I'_{D.C.}$	$E'_{D.C.}$	$K.W.'_{D.C.}$	$I_{AVE.}$	$E_{AVE.}$	$K.W._{AVE.}$	%E	$WM_{A.C.}$	f
11	4.7	220.	.94	1.04	.910	6.2	118	.76	6.2	118	.76	6.2	118	.76	81.0	.64	60
7	7.3	"	1.435	1.63	.896	10.5	112.5	1.16	10.5	113.5	1.16	10.5	113	1.16	81.2	.975	"
4	11.1	"	2.46	2.46	.886	15.15	114.0	1.76	15.15	115.2	1.80	15.5	114.6	1.78	82.5	1.47	"
2	14.4	"	2.90	2.93	.926	19.8	119.5	2.44	19.8	120.0	2.44	20.1	119.7	2.44	83.2	2.0	"
2	16.0	"	3.22	3.52	.912	22.2	116.0	2.69	22.2	116.0	2.69	22.2	116.0	2.69	83.5	2.2	"
RUN 2					REACTANCE POINT #2												
11	3.32	220.	.645	.713	.905	4.60	120.7	.52	4.6	120.7	.52	4.60	120.2	.52	80.7	.44	60
5	6.9	"	1.41	1.54	.928	10.2	113.5	1.17	10.2	113.5	1.170	10.2	113.5	1.17	83.0	.96	"
1	10.5	"	2.10	2.31	.910	15.5	120.0	1.87	15.3	121.5	1.80	15.4	120.7	1.83	87.2	1.43	"
1	13.8	"	2.70	3.04	.890	20.1	117.0	2.42	20.1	118.0	2.48	20.1	117.5	2.45	90.8	1.84	"
1	15.2	"	2.98	3.34	.892	22.1	115.5	2.65	22.2	117.0	2.72	22.2	116.2	2.69	90.4	2.05	"
RUN 3					REACTANCE POINT #3												
3	3.70	220	.63	.69	.910	4.5	118.1	.50	4.5	118.1	.60	4.50	118.1	.600	79.4	.43	60
1	7.0	"	1.39	1.511	.900	10.0	114.5	1.15	10.0	114.5	1.15	10.0	114.5	1.16	83.0	.95	"
1	9.8	"	1.97	2.16	.885	15.2	110.2	1.70	15.2	112	1.75	15.2	111.1	1.725	90.1	1.30	"
1	12.9	"	2.54	2.84	.895	20.1	108.5	2.25	20.2	110	2.31	20.2	109.2	2.28	89.8	1.73	"
1	14.0	"	2.74	3.08	.890	21.95	107.5	2.43	21.9	108.9	2.48	21.9	108.2	2.455	89.5	1.87	"
RUN 4					REACTANCE POINT #4												
1	2.8	220	.592	.615	.95	4.8	110.0	.53	4.8	111.0	.535	4.8	110.5	.533	91.0	.40	60
1	6.0	"	1.19	1.32	.889	9.9	105.5	1.05	10.1	106.7	1.09	10.0	105.7	1.07	91.5	.86	"
1	9.0	"	1.77	1.98	.896	15.0	102.0	1.57	15.1	103.2	1.59	15.05	102.6	1.58	89.4	1.27	"
1	11.9	"	2.34	2.62	.886	20.0	100.0	2.05	20.0	101.0	2.09	20.0	100.5	2.07	88.5	1.60	"
1	13.0	"	2.55	2.86	.892	22.0	100.8	2.22	21.95	100.0	2.28	22.0	100.4	2.25	88.2	1.74	"
RUN 5					REACTANCE POINT #5												
1	2.8	220	.572	.606	.942	5.0	100.5	.505	5.0	100.2	.53	5.0	100.4	.517	90.5	.59	60
1	5.7	"	1.10	1.25	.880	10.0	95.5	.97	10.1	96.8	.95	10.05	96.1	.96	87.2	.75	"
1	8.2	"	1.73	1.85	.935	15.05	91.9	1.41	15.0	91.9	1.47	15.0	91.9	1.41	81.7	1.18	"
1	10.7	"	2.23	2.40	.930	19.6	91.0	1.81	19.6	91.0	1.81	19.6	91.0	1.81	81.4	1.64	"
1	12.0	"	2.38	2.64	.903	22.1	89.6	2.05	22.1	91.5	2.09	22.1	90.5	2.07	86.0	1.62	"

TABLE II.

PEAKED WAVE; 1100/220 VOLTS.

RUN 1. REACTANCE POINT #1.

R	I_{AC}	E_{AC}	$KW_{A.C.}$	$KW_{COR.}$	EI_{AC}	P.F.	F~	I_{DC}	E_{DC}	$K.W._{DC}$	I'_{DC}	E'_{DC}	$K.W.'_{DC}$	$I_{AVE.}$	E_{AVE}	$K.W._{AVE}$	%E
1	7.4	"	.92	1.35	1.63	.830	"	10.1	118	1.19	10	119.2	1.23	10.06	118.6	1.21	89.8
1	11.1	"	1.35	1.98	2.44	.812	"	15.7	118	1.72	15.7	113.5	1.79	15.7	115.7	1.75	88.5
1	14.8	"	1.78	2.61	3.26	.800	"	20.3	109	2.27	20.2	110	2.32	20.25	109.5	2.295	88.7
1	16.55	"	1.98	2.90	3.64	.798	"	22.7	107.8	2.53	22.7	109	2.58	22.7	108.4	2.555	88.0
RUN 2						REACTANCE POINT #2											
2	3.0	220	.57	.542	.66	.822	60	4.56	120	.52	4.4	121.0	.54	4.48	120.5	.53	97.8
1	6.8	"	.84	1.23	1.49	.825	"	9.90	110	1.08	9.9	110.6	1.12	9.90	110.3	1.10	89.4
1	10.55	"	1.25	1.83	2.28	.810	"	14.95	105	1.59	14.95	106.5	1.63	14.95	105.7	1.61	88.0
1	13.6	"	1.65	2.42	3.00	.809	"	19.90	102.5	2.08	19.9	104.5	2.14	19.90	103.2	2.11	87.3
1	15.15	"	1.82	2.67	3.34	.770	"	22.1	100.5	2.28	22.1	102.0	2.34	22.10	101.2	2.31	86.5
RUN 3						REACTANCE POINT #3											
1	2.6	220	.35	.513	.573	.896	60	4.30	113.0	.470	4.3	113.5	.48	4.30	113.2	.475	92.8
1	6.6	"	.81	1.19	1.45	.822	"	10.2	101.0	1.035	10.2	102.0	1.05	10.2	101.6	1.04	87.4
1	9.55	"	1.16	1.68	2.10	.808	"	14.9	97.2	1.47	14.85	98.0	1.46	14.87	97.6	1.47	87.0
1	12.9	"	1.56	2.28	2.84	.802	"	20.2	95.0	1.96	20.25	95.5	2.00	20.23	95.2	1.98	86.6
1	14.1	"	1.69	2.50	3.11	.803	"	22.1	93.0	2.12	22.0	94.5	2.15	22.05	93.8	2.14	86.0
RUN 4						REACTANCE POINT # 4											
1	2.8	220	.38	.558	.616	.906	60	5.0	102.5	.52	5	103	.51	5.0	102.7	.51	91.5
1	6.0	"	.73	1.07	1.32	.811	"	9.95	93.5	.94	10	94	.95	9.97	93.7	.945	88.3
1	8.9	"	1.09	1.60	1.96	.816	"	14.96	89.5	1.37	14.9	90.5	1.40	14.93	90.0	1.38	86.4
1	11.8	"	1.42	2.08	2.59	.806	"	19.9	87.0	1.77	19.95	87.5	1.80	19.92	87.3	1.79	86.0
1	13.0	"	1.57	2.30	2.86	.803	"	22.05	86.0	1.96	22.05	87.0	1.98	22.05	86.5	1.97	85.6
RUN 5						REACTANCE POINT #5											
1	2.6	220.	.37	.543	.573	.960	60	6.3	93.5	.49	6.3	93.6	.495	6.3	93.5	.492	90.7
1	5.4	"	.69	1.01	1.19	.850	"	10.05	86.5	.88	10.1	87.0	.890	10.07	86.7	.885	87.6
1	8.22	"	1.02	1.49	1.81	.823	"	16.05	82.0	1.26	16.1	83.5	1.29	16.07	82.7	1.28	86.0
1	10.9	"	1.32	1.94	2.40	.809	"	20.0	79.5	1.62	20.0	80.0	1.63	20.0	79.7	1.63	84.1
1	12.0	"	1.46	2.15	2.64	.806	"	22.05	78.0	1.76	22.0	79.0	1.78	22.02	78.5	1.77	83.1

TABLE III.

DATA AND CALCULATIONS ON THE MURPHY RECTIFIER

SINE WAVE RUN 2 REACTANCE PT. #2.

I_{AC}	E_{AC}	$K.W._{AC}$	f	EI_{AC}	P.F.	I_{DC}	E_{DC}	KW_{DC}	I'_{DC}	E'_{DC}	KW'_{DC}	KW_{AVE}	%E
4.0	120	.25	60	.48	.522	4.0	35.0	.14	4.2	35.0	.13	.135	54.0
6.3	″	.41	″	.756	.543	6.0	38.0	.225	6.2	37.5	.225	.225	55.0
8.5	″	.60	″	1.02	.588	8.0	41.0	.340	8.8	41.0	.38	.36	63.4
10.5	″	.67	″	1.26	.532	10.0	44.0	.430	10.0	43.0	.445	.439	66.4
12.4	″	.80	″	1.49	.537	12.0	47.0	.590	11.8	45.0	.545	.575	68.2
RUN 3.				REACTANCE POINT #3.									
4	120	.25	60	.48	.522	4	42.5	.15	3.5	35.0	.12	.135	54
5.5	″	.30	″	.65	.555	6	36.0	.19	6.0	41.0	.29	.240	60.7
6.3	″	.57	″	1.03	.554	8	44.0	.37	8.0	45.0	.36	.365	64.1
8.6	″	.73	″	1.25	.584	10	42.5	.59	10	48.0	.47	.485	66.4
12.5	″	.82	″	1.50	.547	12	46.0	.55	12	45.0	.56	.555	67.8
RUN 1.				REACTANCE POINT #4									
4	120	.24	60	.48	.50	4	30	.11	4	32	.11	.11	45.8
6	″	.38	″	.72	.528	6	30	.18	6.5	30	.21	.195	51.3
		CARBONS SHORTED FOR HIGHER LOADS.											
RUN 4.				REACTANCE POINT #5.									
7.5	120	.545	60	.90	.606	4	47.0	.36	3.9	47.0	.34	.35	64.3
12.3	″	.81	″	1.48	.547	6	47.5	.56	6	47.5	.57	.565	69.9
16.25	″	1.055	″	1.95	.542	8	46.5	.74	8	46.5	.75	.745	70.6
20.2	″	1.27	″	2.42	.525	10	45.0	.92	10	45.0	.90	.91	71.6
22.5	″	1.40	″	2.70	.519	11	45.0	.99	11	45.0	.99	.99	70.6
RUN 5				REACTANCE POINT #6.									
8.2	120	.595	60	.985	.604	4	52.0	.40	4	51.1	.39	.395	66.5
13	″	.90	″	1.56	.576	6.2	51.0	.63	6.2	51.0	.63	.630	70.0
16.3	″	1.10	″	1.96	.567	8	50.0	.80	8	49.5	.79	.795	72.2
20.35	″	1.35	″	2.44	.553	10	48.0	.96	10	48.0	.96	.96	71.2
22.5	″	1.48	″	2.70	.548	11	47.5	1.05	11	47.5	1.04	1.045	70.8

TABLE IV.

PEAKED WAVE. 1100/120 VOLTS.

RUN 1. REACTANCE POINT #1.

I_{AC}	E_{AC}	KW_{AC}	f	EI_{AC}	P.F.	I_{DC}	E_{DC}	KW_{DC}	I'_{DC}	E'_{DC}	KW'_{DC}	KW_{AVE}	%E
3.8	120	.25	60	.456	.548	3.5	42.5	.15	3.5	42.5	.142	.146	58.4
6.3	″	.40	″	.756	.529	6.0	41.0	.26	6	41.5	.25	.255	63.8
8.4	″	.50	″	1.01	.496	8.0	40.5	.335	8	40.5	.36	.347	69.5
10.6	″	.60	″	1.27	.473	10.1	40.0	.406	10.2	40.0	.405	.406	67.6
12.8	″	.75	″	1.54	.474	12.0	40.5	.52	12.2	40.0	.50	.51	68.0
RUN 2.				REACTANCE POINT #2.									
4	120	.23	60	.48	.479	4	37.5	.13	3.7	36.5	.13	.13	56.6
6.35	″	.35	″	.761	.460	6	36.0	.23	6.1	36.0	.23	.23	65.8
8.25	″	.45	″	.990	.455	8	34.5	.29	8.0	34.0	.285	.287	63.8
10.4	″	.545	″	1.25	.436	10	32.5	.33	10	33.5	.36	.345	63.3
12.3	″	.61	″	1.47	.415	12	33.0	.41	12	33.0	.406	.407	66.8
RUN 3.				REACTANCE POINT #3.									
4	120	.25	60	.48	.522	4	38.0	.15	4	38.5	.15	.15	60.2
6.2	″	.38	″	.745	.510	6	38.5	.24	6	38.5	.24	.24	63.3
8.2	″	.47	″	.985	.478	8	38.0	.31	7.9	38.0	.315	.312	66.4
10.5	″	.58	″	1.26	.460	10.6	38.0	.41	10	38.0	.36	.385	66.5
12.4	″	.65	″	1.49	.436	12	37.0	.42	12	36.5	.43	.425	65.5
RUN 4				REACTANCE POINT #4.									
4.4	120	.30	60	.528	.568	4.2	43.5	.18	4.2	43.3	.18	.18	.601
6.4	″	.40	″	.768	.521	6.0	42.0	.26	6.0	42.0	.26	.26	.650
8.3	″	.50	″	.996	.502	8.0	41.0	.33	8.0	41.5	.33	.33	66.0
10.5	″	.615	″	1.26	.488	10.2	41.5	.435	10	41.5	.41	.422	68.7
12.4	″	.70	″	1.49	.470	12.0	40.5	.490	12	40.5	.49	.49	70.1
RUN 5.				REACTANCE POINT #5.									
4.5	120	.30	60	.54	.528	4.2	46.0	.195	4.1	45	.19	.192	69.0
6.5	″	.45	″	.78	.577	6.2	45.0	.29	6.2	45	.28	.285	63.4
8.25	″	.55	″	.99	.557	8.0	46.0	.37	8.0	45	.365	.367	66.8
10.65	″	.65	″	1.28	.508	10.2	44.0	.44	10.2	44	.45	.445	68.6
13.0	″	.80	″	1.56	.513	12.0	45.5	.56	12.0	43	.56	.560	70.1
RUN 6				REACTANCE POINT #6.									
4.4	120	.32	60	.528	.607	4	49.0	.19	4	48	.19	.19	63
6.4	″	.45	″	.768	.586	6	47.5	.29	6	47.5	.29	.29	64.6
8.7	″	.60	″	1.04	.577	8.1	47.5	.41	8	46.5	.38	.396	65.9
10.65	″	.70	″	1.28	.546	10.1	47.0	.48	10.1	46.5	.48	.48	68.6
12.5	″	.80	″	1.50	.533	12.0	46.5	.56	12	46	.566	.562	70.3